Research Note
UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
INTERMOUNTAIN FOREST & RANGE EXPERIMENT STATION
OGDEN, UTAH 84401

U.S. Forest Service
Research Note INT-73

1967

SOIL MOISTURE DEPLETION BY ASPEN IN CENTRAL UTAH

by

Ronald K. Tew[1]

ABSTRACT

Aspect and elevation of site and age of vegetation affect the amount of soil moisture depleted by aspen (Populus tremuloides Michx.) during the growing season in central Utah. Clones on west aspects used more soil moisture than those on either north- or south-facing slopes. Differences in elevation had little effect on the amount of soil moisture depleted by mature aspen, but sprout stands used significantly greater amounts of soil moisture on the lower elevation sites. As much as 5 inches of moisture was conserved in the upper 6 feet of soil during the first season after aspen removal, but as sprout stands became reestablished, there was a decrease in these moisture savings.

Quaking aspen (Populus tremuloides Michx.) occupies more than 1.3 million acres in Utah. Management of this species, along with its associated understory, is important from the point of view of water yield, grazing, timber, wildlife, and aesthetic values. Aspen roots extend to depths exceeding 9 feet,[2] thereby enabling the tree to deplete soil moisture to those depths. Management of aspen, therefore, should include consideration of its water consumption. Some aspen stands having little commercial value might be converted to shallow-rooted vegetation that has greater economic potential, with a resulting increase in the yield of water from the area. However, many things must be considered before any such conversion practices are attempted. Aspen provides valuable watershed protection. It grows on deep fertile soils and contributes to their development. It is an important browse species for big game and livestock, and its understory produces large amounts of herbage. It has aesthetic value, largely because of its brilliant autumn colors.

---

[1] Associate Plant Physiologist, stationed in Logan, Utah, at the Forestry Sciences Laboratory which is maintained in cooperation with Utah State University.

[2] Gifford, Gerald F. Aspen root studies on three sites in northern Utah. Amer. Midland Natur. 75(1): 132-141. 1966.

For the research program in water yield improvement in the Intermountain area, information on soil moisture depletion by aspen was needed for purposes of comparison. The research reported in the present study was initiated to supply this information with respect to effects of aspect and elevation of site and age of vegetation.

METHODS

Mature aspen clones were selected at six sites in Ephraim Canyon in central Utah. These sites included three aspects (north, south, and west) at each of two elevations (7,900 and 9,200 feet). Few aspen grow below 7,900 feet in this area, although a considerable number occur above 9,200 feet, especially on south-facing slopes. Clones were selected for uniformity in appearance. At each elevation, all study areas were chosen within a quarter mile of each other to provide similar climatic conditions on comparable sites.

At each site, an area 40 by 40 feet was divided into four square plots. Boundaries between plots were trenched to a 2-foot depth, so that the lateral root systems were severed and prevented from transporting water across plot boundaries. To impede regrowth of these roots, roofing paper was placed in the trenches, and the trenches were refilled.

During July 1963, the aspen was clearcut and removed from two of the plots at each site and a young sprout stand was allowed to develop. A buffer strip 20 feet wide also was clearcut on the outer edges of the experimental area at each site. Thus the effects of 12 treatment combinations of aspect, elevation, and cutting on water use by aspen were compared. This arrangement provided for two replications of each combination.

To permit use of a neutron soil moisture probe, access tubing was installed to a 6-foot depth by means of a jackhammer-type drill. Two tubes were randomly located on each of the 24 plots, providing two soil moisture sampling points for each replication of the treatment combinations. Measurements were made on all plots three times (May or early June, late July, and mid-September) each year from 1964 through 1966.

A soil pit 6 feet deep was dug adjacent to each site, the profile was described, and samples were obtained from each horizon. Texture was determined by the Bouyoucos hydrometer method, organic matter content by wet digestion with chromic acid, and lime content by acid neutralization; moisture-holding properties were evaluated with a pressure membrane apparatus.

SOILS

The moisture-holding capacity of the soils on all sites was closely related to the clay content, rock content, and depth of soil development. The soil on all sites had developed from limestone parent material. It was high in clay content, although the amount of clay varied noticeably from one aspect to another. South aspects had soil that was relatively low in clay, approximately 30 percent at both elevations. About 46 inches of rock-free soil had developed on the south-facing slope at the lower elevation. However, in laboratory tests, this soil was found to have only a moderate moisture-holding capacity, as compared with soil from plots on the other aspects at that elevation. At 9,200 feet (the upper elevation) the soil at the south aspect site contained many large rocks. There, only 16 inches of soil had developed, below which lay a considerable amount of sand and rock.

The north aspect at 7,900 feet had the deepest soil, approximately 48 inches. Because clay content was near the 50-percent level throughout the entire profile, moisture-holding capacity was relatively uniform. At 9,200 feet, 33 inches of soil had developed; it was approximately 45 percent clay and its organic matter content was high. The solum had very high moisture-holding properties, but an abrupt decrease occurred at the boundary of the somewhat rocky parent material.

Soil on the west aspect at 9,200 feet was 48 inches deep; a 12-inch B_2 horizon contained 60 percent clay. Little sand or rock was present. Moisture-holding capacity was high. At 7,900 feet the soil on the west aspect was not as deep, consisting of only 29 inches of well-developed soil, but the moisture-holding capacity was high throughout the entire 6 feet.

SOIL MOISTURE DEPLETION

The effects of differences in aspect and elevation of site, and age and density of vegetation on soil moisture depletion were tested during three growing seasons. An analysis of variance was used to determine whether differences in results were significant. The effect of each variable was confounded with soil differences and clonal variation among sites, so that only broad generalizations are possible.

Aspect.--During all 3 years, the largest amounts of soil moisture were removed by aspen clones growing on west exposures (table 1). Moisture depletion on north- and south-facing sites at both elevations was similar during all years. However, the difference between mature and sprout stands was greatest on north-facing slopes. There, in 1964, at the upper elevation, the sprout stand used 5 inches less soil moisture than the mature stand.

More soil moisture was depleted on all aspects during 1964 than during either 1965 or 1966 because less precipitation was received during the 1964 growing season. In contrast, an exceptionally wet year occurred in 1965, and as a result, only small differences in soil moisture depletion between aspects were observed.

Elevation.--Soil moisture losses under mature aspen on comparable sites were similar at both elevations. However, sprout stands consistently used more moisture at the lower elevation. As a result, the data show that a greater saving of soil moisture was achieved at the higher elevation by clearcutting (table 1). The difference is especially pronounced for the wet season of 1965.

Age of vegetation.--Mature stands of aspen used significantly more moisture than did sprout stands during all 3 years. The cutting treatment, which replaced mature stands with sprouts, had the greatest influence on north aspects at both elevations (table 1). The differences between mature and sprout stands decreased on all aspects from 1964 to 1966, as would be expected when the young sprouts grew and more fully occupied the site. Depending on site characteristics, the clearcutting treatment resulted in conservation of 1 to 5 inches of soil moisture in the upper 6 feet of soil.

Quantity of vegetation.--The number and basal area of aspen stems were inventoried on all plots of mature aspen (table 2). On comparable aspects, the plots at the higher elevation had a greater tree population. More basal area at the higher elevation on south and west aspects also was noted, but there was little difference between elevations on north aspects.

Table 1.--Soil moisture depletion during three growing seasons

Site and year	Mature stands	Sprout stands	Difference
	Inches		
	7,900-FOOT ELEVATION		
North aspect			
1964	7.72	4.31	3.41
1965	4.23	1.30	2.93
1966	5.13	3.98	1.15
South aspect			
1964	7.46	6.43	1.03
1965	4.72	3.41	1.31
1966	6.41	5.78	0.63
West aspect			
1964	9.91	9.06	0.85
1965	5.82	5.45	0.37
1966	7.63	7.09	0.54
	9,200-FOOT ELEVATION		
North aspect			
1964	8.25	3.04	5.21
1965	4.66	0.07	4.59
1966	7.34	2.53	4.81
South aspect			
1964	7.44	5.70	1.74
1965	4.45	0.87	3.58
1966	7.17	6.21	0.96
West aspect			
1964	9.56	7.31	2.25
1965	7.01	1.71	5.30
1966	8.37	6.91	1.46

Table 2.--Average stem density and basal area on plots of mature aspen

Aspect	Stem density per acre		Basal area	
	7,900-ft. elev.	9,200-ft. elev.	7,900-ft. elev.	9,200 ft. elev.
North	152	250	180.8	148.6
South	163	207	139.5	204.5
West	120	272	166.4	252.4

Soil moisture depletion was consistent with vegetation density when differences between mature and sprout stands were considered. Little difference could be noted between the mature stands at the two elevations, so that differences in vegetation density are unimportant. From evidence in the trenches dug on each plot, it appeared that aspen roots were quite uniformly distributed over the entire plot, regardless of the location or spacing of trees.

Season of use.--The greatest depletion of soil moisture occurred during the early part of the growing season. For example, in 1966 the average soil moisture depletion for all plots at 7,900 feet elevation was 4.78 inches between May 25 and July 13. From then until September 22 another 1.23 inches was depleted, making a total of 6.01 inches. During the same time interval, for the sites at 9,200 feet the moisture depletion was 5.56 and 0.87 inches. The time of maximum depletion varied from year to year, depending to some extent on the timing and amount of summer rainfall in relation to the time soil moisture measurements were made. Late season moisture losses generally were from the lower portions of the soil profile.

Depth of loss.--On all plots, use of soil moisture decreased with increasing depth in the profile. Table 3 shows maximum water loss on the various sites, that is, the water loss that might be expected, calculated on the basis of the observed maximum differences between spring and fall readings obtained during the 3 years. Approximately equal amounts were taken from the upper 4 feet of soil by mature and sprout stands. Mature aspen showed only moderate decreases in moisture use in soil levels above the 5-foot depth. A more rapid decrease was observed on plots having sprout stands; the quantities of water removed from the 5- and 6-foot depth levels were relatively small. At both elevations, this pattern of soil moisture removal was especially pronounced on north aspects and was least evident on south aspects.

EVAPOTRANSPIRATION

Table 4 shows the total evapotranspiration during three growing seasons calculated as growing-season precipitation plus soil moisture depletion. This assumption neglects any deep seepage or overland flow that might have occurred during the growing season. Precipitation during individual storms was greater at the higher elevation than at the lower, but the total precipitation for the higher sites was less because the growing season was shorter.

Evapotranspiration during 1964 and 1966 was similar on comparable sites, although slightly greater losses were observed in 1966 from sprout stands. Little difference was noted between elevations. During 1965, when precipitation was exceptionally great, evapotranspiration was also greater, resulting in approximately 3 inches more moisture loss than in either 1964 or 1966. Soil moisture depletion was much less, however, so that more soil moisture was retained at the end of the growing season.

DISCUSSION

Soil moisture depletion by aspen is affected by the aspect and elevation of the site and by the age of the vegetation. Some of the variation attributable to aspect and elevation was probably caused by differences in soil depth and quality. Because south-facing slopes receive more solar energy than either the north- or west-facing slopes, they might be expected to have higher rates of soil moisture loss. Since, instead the highest rates were for west-facing slopes, other factors, such as differences in soil properties, must dominate.

Table 3.--Patterns of soil moisture depletion by aspen according to plot treatment

Treatment	Maximum water loss[1] By 1-ft depth intervals 0-1	1-2	2-3	3-4	4-5	5-6	Total	Difference mature trees vs. sprouts
	Inches							
7,900-FOOT ELEVATION								
North aspect								
Mature trees	1.75	1.65	1.68	0.90	1.19	0.85	8.02	
Sprouts	1.51	1.33	0.92	0.87	0.23	0.39	5.25	2.77
South aspect								
Mature trees	1.44	1.72	1.13	1.32	1.13	0.75	7.49	
Sprouts	1.67	1.74	1.47	1.17	0.78	0.50	7.33	0.16
West aspect								
Mature trees	2.48	2.85	2.44	1.56	1.62	1.37	12.32	
Sprouts	2.62	2.96	2.64	1.65	1.06	0.62	11.55	0.77
9,200-FOOT ELEVATION								
North aspect								
Mature trees	2.07	1.57	1.62	1.20	1.44	1.51	9.41	
Sprouts	1.74	0.89	0.68	0.50	0.44	0.42	4.67	4.74
South aspect								
Mature trees	2.03	1.74	1.25	1.26	1.00	0.96	8.24	
Sprouts	1.90	1.15	1.38	1.20	0.91	0.70	7.24	1.00
West aspect								
Mature trees	2.54	2.32	1.39	1.75	1.26	1.26	10.52	
Sprouts	2.39	1.74	1.48	1.23	0.57	0.51	7.92	2.60

[1]Based on maximum differences observed between spring and fall readings from 1964 through 1966.

Table 4.--Evapotranspirational losses[1] during three growing seasons according to plot treatment and ages of vegetation

Treatment	1964 Precip.	1964 ET.	1965 Precip.	1965 ET.	1966 Precip.	1966 ET.
	Inches					
7,900-FOOT ELEVATION						
North aspect						
Mature trees	3.98	11.70	10.65	14.88	4.80	9.93
Sprouts		8.29		11.95		8.78
South aspect						
Mature trees	3.98	11.44	10.65	15.37	4.80	11.21
Sprouts		10.41		14.06		10.58
West aspect						
Mature trees	3.98	13.89	10.65	16.47	4.80	12.43
Sprouts		13.04		16.10		11.89
9,200-FOOT ELEVATION						
North aspect						
Mature trees	3.78	12.03	9.28	13.94	5.55	12.89
Sprouts		6.82		9.35		8.08
South aspect						
Mature trees	3.78	11.22	9.28	13.73	5.55	12.72
Sprouts		9.48		10.15		11.76
West aspect						
Mature trees	3.78	13.34	9.28	16.31	5.55	13.92
Sprouts		11.09		10.99		12.46
Average						
Mature trees		12.27		15.11		12.18
Sprouts		9.86		12.10		10.59

[1] Based on soil moisture depletion plus precipitation during the growing season.

At both elevations, the greatest differences between mature and sprout stands were observed on north slopes. Therefore, in planning treatment of an area to increase streamflow, aspect should be considered, since north slopes apparently have the greatest potential for supplying additional water.

The difference in treatment effects at different elevations may be related to leafing dates. Lower elevation clones began leafing out approximately May 25 and higher elevation clones began during the first week of June. Since leaves remained on the trees later into the fall at the lower elevation, there was a longer period for transpiration at that level. Perhaps due to this longer period, total use of soil moisture by sprout stands was greater at the lower elevations. However, mature aspen stands on comparable sites used similar amounts of soil moisture at both elevations. If aspen is to be removed for the purpose of increasing water yields, treatments at higher elevations are likely to be most successful.

If savings in soil moisture over a period of several years are desired, some type of control program is required to suppress sprout numbers or growth. If aspen is eradicated and shallow-rooted plants are established, losses that still occur deep in the profile under sprout stands may be eliminated. Whether the deep parent root systems are supporting aspen sprouts or old trees, soil moisture depletion will continue to at least a 6-foot depth, as indicated in table 3.

More must be learned before any specific treatment to increase water yields can be recommended. This study shows that moisture depletion is only temporarily reduced by cutting aspen stands. Conversion to another vegetation type appears to be necessary if moisture losses are to be reduced over any significant period. Potential replacement species for aspen need to be investigated with respect to their rooting depths, their soil moisture depletion patterns, and their ability to become established on aspen sites. Further, the effects, both adverse and favorable, that the conversion may have on the site require investigation. Therefore, no management decision to remove aspen for the purpose of increasing water yields should be made without careful study of site conditions.